Feasibility Study for the use of Chimney Drains to reduce acid costs.

The economic evaluation for using the acid from the Chimney Drains to offset the treatment costs for the Circulating Water Makeup are not justified. The cost savings of the acid were calculated on the basis of a theoretical concentration and from a titrated sample of the Chimney Acid (see attached Mathcad document). The calculated cost savings from the titrated sample gave a cost savings per year of $4,065. The calculated cost savings from the theoretical concentration gave a cost savings of $8,638. The difference in the concentration is most likely due to the contamination of the chimney acid.

pH of Sulfuric Acid using Molar Concentration

$H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$ (1) $ka_1=[H_3O^+][HSO_4] / [H_2SO_4]$

Strong Acid - molar concentration can be considered equal to H_3O^+ concentration as ionization is essentially complete.

$HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$ (2) $ka_2=[H_3O^+][SO_4] / [HSO_4]$

The ionization from the H_3O^+ in the second is not complete and the concentration is determined using the ionization constant for this reaction.

$H_3O^+_1 = H1$ $H_3O^+_2 = H2$ $HSO_4^- = C_m - x$ $SO_4 = x$ $ka_2 = x^2 / C_m - x$

Cm = Molar concentration

$Cm := .0068$ $ka1 := Cm$ $ka2 := 1.2 \cdot 10^{-2}$ $Hyd_1 := Cm$ $Hyd_2 = x$ $i := 1,2..20$

$f(x) := x^2 + (ka2 + Hyd_1) \cdot x - ka2 \cdot Hyd_1$

$y := f(x)\ coeffs, x \rightarrow \begin{pmatrix} -0.0000816 \\ 0.0188 \\ 1 \end{pmatrix}$ $r := polyroots(y)$ $r_1 = 3.637 \times 10^{-3}$

$Hyd := r + Cm$ $pH := -\log(Hyd)$ $pH_1 = 1.981$

pH between 1 and 3 gives a molar concentration between .0005 and .09 mol/L

Calculation of Molar Concentration of 93% Sulfuric Acid

Molar Concentration $Cm = (n_{substance} / V_{solution}) * 100\%$

Mass Percentage $C_{\%w} = (m_{substance} / (m_{substance} + m_{splvent}))*100\%$

$Cm = 10 * C_{\%w} * \rho / M_m$ M_m = molar mass ρ = density

$Mm := 98.078 \frac{gm}{mol}$ $\rho := 1.8354 \frac{gm}{mL}$ $C\% := .93$

$molarconc := \frac{C\% \cdot \rho}{Mm}$ $molarconc = 17.404 \frac{mol}{L}$

Amount of Chimney Acid required to be equivalent to 1 ton of 93% Sulfuric Acid

1) The measured pH of the Chimney Acid is 1.98
2) The calculated Molar Concentration at this pH would then be 0.0068 mol/L

$ch\_acid\_conc := Cm \cdot \frac{mol}{L}$ $Ma := molarconc$ $molarmass := 98.078 \frac{gm}{mol}$ $SG93 := 1.8354$

$\rho 93\% := 15.286 \frac{lb}{gal}$ from table $acid93\% := \frac{1}{\rho 93\%}$ $acid93\% = 130.839 \frac{gal}{ton}$

$ch\_acid\_equivalent := \frac{molarconc}{ch\_acid\_conc}$ $ch\_acid\_equivalent = 2.559 \times 10^{3}$

Cost of 93% or 66° Baume' Sulfuric Acid is $220 / ton.

Flowrate was estimated as the flow from the Chimney Drains is not consistent.

$ch\_acid\_flowrate := 25 \frac{gal}{min}$ $ch\_acid\_flowrate = 1.315 \times 10^{7} \frac{gal}{yr}$ $cost\_93\%acid := \frac{220}{ton}$

$Acid\_Savings := \frac{\left(\frac{ch\_acid\_flowrate}{ch\_acid\_equivalent}\right)}{acid93\%} \cdot cost\_93\%acid$ $Acid\_Savings = 8.638 \times 10^{3} \frac{1}{yr}$

Acid Savings for a calculated molar concentration of .0068 mol/L is $8,638.00 / yr.

Titration of Chimney Acid Sample

.8 ml of 2 N NaOH were used to titrate 25 ml of chimney acid solution

$NaOH := .2 \frac{mol}{L}$ $Acid := 25mL$

$Acid\_Conc := \frac{NaOH}{2} \cdot \frac{.8mL}{25mL}$ $Acid\_Conc = 3.2 \times 10^{-3} \frac{mol}{L}$

Acid Savings for the titrated sample molar concentration of .0032 mol/L is $4,065.00 / yr.